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A Study of Municipal Wastewater Toxicity, Annacis Island Sewage Treatment Plant, October, 1976.

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Pacific Region
September, 1977

A STUDY OF MUNICIPAL WASTEWATER TOXICITY, ANNACIS ISLAND SEWAGE TREATMENT PLANT, OCTOBER, 1976

by

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ABSTRACT

A wastewater toxicity study of the Annacis Island Sewage Treatment Plant was conducted by personnel from the Environmetal Protection Service, Pacific Region.

The objectives of this study, conducted from October 4-8, 1976, were as follows:

(1) to determine the extent of toxicity removal achieved by the sewage treatment plant, i.e. primary treatment;
(2) to determine the effect of chlorination on the toxicity of the effluent;
(3) to determine the effect of dechlorination on the toxicity of the effluent;
(4) to relate the toxicity of the influent, primary effluent, chlorinated effluent and dechlorinated effluent to the concentrations of certain known toxic substances, and;
(5) to determine the incidence and the extent of removal of polychlorinated biphenyls.

The study also included the collection of information concerning such factors as plant design and actual loading, chlorine dosage and sulfur dioxide dosage. This information was collected to assist in interpreting data gathered for the objectives listed above.

This report contains the results of bioassay determinations and chemical analyses of samples collected during the survey at various treatment plant locations.

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LIST OF ABBREVIATIONS

BOD_5	5 day biochemical oxygen demand
$CaCO_3$	calcium carbonate
CFS	Cubic feet per second
Cl_2	chlorine
COD	chemical oxygen demand
DO	dissolved oxygen
GLC	gas liquid chromatography
g/l	grams per liter
gal/ft2/day	gallons per square foot per day
GVRD	Greater Vancouver Regional District
GVS & DD	Greater Vancouver Sewage and Drainage District
hr	hour(s)
ImpMGD	million imperial gallons per day
l	liter(s)
LAS	linear alkylate sulfonate
mg/l	milligrams per liter
MPN	most probable number
NFR	non filterable residue
PCB	poly chlorinated biphenyls
ppb	parts per billion
ppm	parts per million
SO_2	sulfur dioxide
STP	sewage treatment plant
Tc	toxicity concentration
TRC	total residual chlorine
TU	toxic unit
µg/l	micrograms per liter

CONCLUSIONS

Based on data collected at the Annacis Island Sewage Treatment Plant from October 4 to 8, 1976 the following conclusions can be made:

(1) Primary sedimentation did not effect raw sewage toxicity. The mean toxicity concentrations Tc, were 1.66 and 1.72 TU for the raw sewage and primary effluent samples respectively;

(2) Chlorination of the primary effluent was responsible for an increase in the mean toxicity concentration of the chlorinated effluent to 2.16 TU. This represents a 30% increase based on the raw sewage samples;

(3) Dechlorination of the chlorinated effluent by SO_2 addition was responsible for a slight decrease in the mean toxicity concentration of the final effluent; A discussion of the results concerning dechlorination is presented in section 4.2

(4) The toxic wastewater constituents which were examined in this study and deemed responsible for the bioassay results were:

   (i) un-ionized ammonia;
   (ii) anionic surfactants, and;
   (iii) compounds formed by chlorination.

(5) The average raw sewage PCB concentration was 0.0585 ppb. The treatment plant reduced PCB levels an average of 42%. All PCB concentrations encountered were significantly low.

1 INTRODUCTION

The Annacis Island Sewage Treatment Plant is operated by the Greater Vancouver Sewerage and Drainage District and treats sewage from the Fraser Sewerage Area which includes all or portions of the municipalities of Burnaby, Langley, Coquitlam, Vancouver, New Westminster, Port Coquitlam, Port Moody, Surrey, Delta and White Rock. New Westminster is the only municipality served by the Annacis Island STP which has a combined sanitary and storm system. However, the New Westminister Interceptor was not connected to the Annacis Island STP until after the survey period.

The total contributory population has been estimated to be 397,000*. The Annacis Island STP treats both domestic and industrial wastewater. A complete list of the major industrial contributors to the sewer system is unavailable. The major types of industries located within the area serviced by Annacis Island STP include:

(1) Pulp and Paper;
(2) Lumber, Treated and Laminated;
(3) Metal, Fabricating and Finishing;
(4) Food Processing;
(5) Petroleum and Petrochemical, and;
(6) Service Related.

A report dealing with an Inventory of Toxic and Hazardous Waste Generation within the City of Vancouver being prepared by the Environmental Protection Service and the City of Vancouver will be published in December, 1977. This report will provide background information concerning the major industrial contributors to the sewerage systems in the City of Vancouver plus the toxic constituents involved with each industry. In addition, a report is presently being published

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* 1976 Preliminary Census Figure, Statistics Canada

by the Westwater Research Centre, University of British Columbia, titled Toxic Substances in The Wastewater from a Metropolitan Area, which deals with the heavy metal concentrations found in wastewater from residential, industrial and mixed areas within the GVRD. Reference should also be made to a report by Tanner, Trasolini and Nemeth (1) which deals with the wastewater characteristics of GVRD treatment plants and major sewers.

Since the above study, conducted in 1973, the Annacis Island STP has been constructed and placed in operation. Some of the trunk sewers monitored during the EPS study such as Burnaby South Slope, Braid and Port Moody, are presently connected to the Annacis Island STP. However,Burnaby South Slope was not connected until after the 1976 survey.

The present survey was conducted as a joint project involving Greater Vancouver Sewerage and Drainage District, the International Pacific Salmon Fisheries Commission and the Environmental Protection Service. The survey consisted of the following programs:

(1) a 4 day composite sampling program;
(2) a 12 hour grab sampling program;
(3) a 24 hour chlorine residual monitoring program, and;
(4) general plant operation data collection.

The objectives of this study, conducted from October 4-8, 1976, were as follows:

(1) to determine the extent of toxicity removal achieved by the sewage treatment plant, i.e. primary treatment;
(2) to determine the effect of chlorination on the toxicity of the effluent;
(3) to determine the effect of dechlorination on the toxicity of the effluent;
(4) to relate the toxicity of the influent, primary effluent, chlorinated effluent and dechlorinated effluent to the

concentrations of certain known toxic substances, and;

(5) to determine the incidence and the extent of removal of polychlorinated biphenyls.

Additional municipal wastewater toxicity studies were conducted at other locations in the Pacific Region during 1976. These surveys were conducted to collect information regarding the ability of various types of sewage treatment systems to remove or reduce wastewater toxicity and to establish the toxicity concentrations involved in each case.

1.1 Annacis Island Sewage Treatment Plant Description

The Annacis Island STP is a primary sedimentation treatment plant with a design average dry weather flowrate of 100 CFS (54 Imp MGD). The treatment components include 4 bar screens, a wet well, 4 raw sewage pumps, 8 aerated grit tanks, 8 sedimentation tanks and a 4 cell chlorine contact tank. Sulfur dioxide is added to the chlorine contact tank approximately 130 feet from the overflow weir to accomplish dechlorination prior to discharge to the Fraser River. A flow diagram showing sample point locations is presented in Figure 1. At the design dry weather flow of 100 CFS the treatment plant has a total hydraulic retention time of 3.5 hours. The general operating characteristics of the Annacis Island STP are outlined in Table 1. The primary sludge is thickened in sludge thickeners and pumped to single stage high rate anaerobic digesters. The final digested sludge is then pumped to sludge lagoons as shown in Figure 1.

1.1.1 Dechlorination.

Dechlorination is the practice of removing all or part of the total chlorine residual remaining after chlorination. Dechlorination becomes necessary in some locations to protect the fisheries resource from the discharge of a toxic chlorinated effluent. Dechlorination at Annacis Island STP is accomplished by the addition of sulfur dioxide near the end of the chlorine contact tank. Sulfur

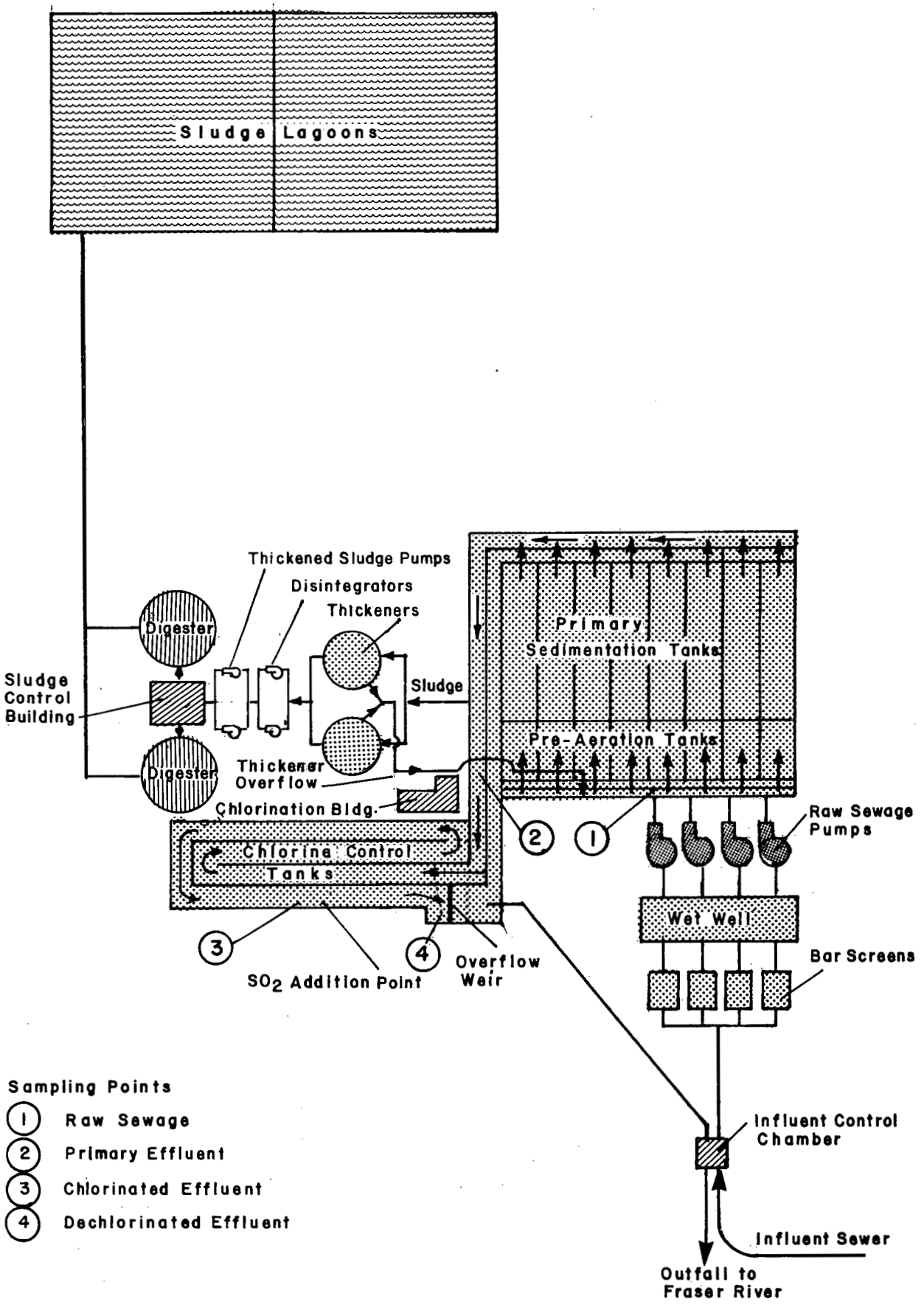

FIGURE 1 ANNACIS ISLAND SEWAGE TREATMENT PLANT-FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

TABLE 1 OPERATIONAL CHARACTERISTICS OF ANNACIS ISLAND SEWAGE TREATMENT PLANT

Design Average Dry Weather 100 CFS
Design Peak Dry Weather 155 CFS
Design Maximum Wet Weather 315 CFS

Treatment Components

1) Bar screens 4 Parallel
2) Raw sewage pump 4 Parallel
3) Pre-aeration Tanks 8 Parallel
4) Primary Sedimentation Tanks 8 Parallel
5) Chlorine Contact Tank 4 Series
6) Sulfur Dioxide Addition

Average Flow (November 1975 - Oct. 1976) = 54.4 CFS
(October 1976) = 56.9 CFS

Detention Times (at D.W.F.)

Pre-aeration Tanks	= 0.6 hr
Sedimentation Tanks	= 1.9 hr
Chlorine Contact Tanks	= 1.0 hr
Total Detention	3.5 hr

Sedimentation Tank Overflow (at D.W.F.) = 700 gal/ft^2/day
Raw Sewage Average BOD = 162 mg/l
NFR = 148 mg/l
COD = 331 mg/l

Final Effluent Average BOD = 114 mg/l
NFR = 58 mg/l
COD = 204 mg/l

Sludge Treatment Components
1) Raw sludge pumps 4 Parallel
2) Sludge Thickeners 2 Parallel
3) Disintegrators 2 Parallel
4) Thickened Sludge Pumps 2 Parallel
5) High rate Anaerobic Digesters 2 Parallel
6) Sludge Lagoons

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dioxide reacts instantaneously with both free and combined chlorine as follows:

Free Chlorine $SO_2 + H_2O \rightarrow H_2SO_3 + HOCl \rightarrow H_2SO_4 + HCl$

Chloramine $NH_2Cl + H_2SO_3 + H_2O \rightarrow NH_4HSO_4 + HCl$

The sulfur dioxide dosage is controlled by means of a chlorine residual analyzer.

1.1.2 Plant Operation. Long term performance data provided by GVS & DD is given in Table 2. This data represents the monthly averages of composite samples taken from the influent and effluent over a one year period. Based on this information the treatment plant accomplished a 29.6% overall reduction in BOD_5, a 60.8% reduction in NFR and a 38.4% reduction in COD. Table 3 lists the data collected by Annacis Island STP personnel during the survey period.

TABLE 2 *SEWAGE TREATMENT PLANT PERFORMANCE DATA
NOVEMBER, 1975 to OCTOBER 1976

Month	Aver. Flow MGD Imp	Influent pH	Influent D.O. mg/l	Influent NFR mg/l	Influent BOD mg/l	Influent COD mg/l	Effluent pH	Effluent D.O. mg/ l	Effluent NFR mg/l	Effluent BOD mg/l	Effluent COD mg/l	Median Total Coliform MPN/100 ml
November 1975	33.0	6.9	3.4	99	88	210	7.1	6.3	52	63	139	2.4×10^7
December	31.2	7.0	5.0	106	97	222	7.1	7.5	52	64	151	9.3×10^6
January 1976	37.5	7.0	5.8	91	87	209	7.2	7.9	52	64	151	5.9×10^6
February	29.8	7.0	3.0	128	116	282	7.0	5.4	62	87	183	9.3×10^6
March	26.1	7.1	2.8	138	154	294	7.2	5.2	59	111	184	9.3×10^6
April	24.5	7.1	2.0	136	166	300	7.1	5.1	62	121	195	9.3×10^6
May	23.5	6.7	0.4	161	176	386	6.8	3.4	58	125	232	6.8×10^3
June	30.0	6.9	0.6	168	187	364	6.7	3.7	65	141	228	3.3×10^3
July	28.5	6.8	0.1	204	224	462	6.6	2.7	61	154	264	1.5×10^4
August	28.8	6.8	0.2	184	206	417	6.6	2.6	56	141	244	1.5×10^4
September	28.9	6.8	0.2	171	211	381	6.6	2.7	52	126	222	5.9×10^3
October	30.6	6.7	0.4	184	240	446	6.4	3.0	62	169	252	4.3×10^3
Average	29.3	6.9	2.0	148	162	331	6.9	4.6	58	114	204	5.6×10^6

*Provided by GVS & DD

TABLE 3 ANNACIS ISLAND STP GVRD ANALYTICAL DATA*
OCTOBER 4 - 8, 1977

Date	Flow			Influent					Effluent				
	Max CFS	Min CFS	Total Imp MGD	pH	D.O. mg/l	NFR mg/l	TR mg/l	BOD mg/l	pH	D.O. mg/l	NFR mg/l	TR mg/l	BOD mg/l
Oct. 4	60	35	23.8	6.9	0.1	215	632		6.7	2.4	58	432	-
Oct. 5	60	30	24.0	6.8	0.2	200	582		6.6	3.1	51	452	-
Oct. 6	65	15	33.9	6.6	0.1	-	-		6.5	3.1	-	-	-
Oct. 7	65	30	36.4	-	-	173	563	333	-	-	51	449	207
Oct. 8	60	30	35.8	6.5	0.1	199	-	-	6.2	2.6	70	-	-

CHLORINATION - DECHLORINATION DATA

Date	Cl_2 dosage ppm	SO_2 Dosage ppm	Cl_2 Residual 5 min contact mg/l	Cl_2 Residual 1 hr contact mg/l	Cl_2 Residual after sulphonation mg/l	SO_2 residual mg/l
Oct. 4	12.3	6.0	3.3	2.0	0	4.1
Oct. 5	17.8	6.0	2.4	1.8	0	1.8
Oct. 6	9.5	6.0	3.0	1.2	0	2.7
Oct. 7	7.8	6.0	-	-		-
Oct. 8	9.1	6.0	3.0	2.2	0	0

*Data provided by GVS & DD

2. PROCEDURES AND METHODS

2.1 Sampling Program

The time proportional 24 hour composite samples were collected at four treatment plant locations as follows:

(1) The raw sewage sample was taken from the sewage lift pump discharge, prior to the pre-aeration tanks. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101 - Spec. Duckbill sampler.

(2) The primary effluent sample was taken from the sedimentation tank overflow channel prior to the chlorine addition point. Approximate 1.1 liter samples were taken every 10 minutes using an Eagle signal timer assembly and a submersible pump.

(3) The chlorinated effluent sample was taken from the chlorine contact tank approximately 40 feet ahead of the sulfur dixoide addition point. Approximate 1.1 liter samples were taken every 10 minutes using an Eagle signal timer assembly and a submersible pump.

(4) The dechlorinated effluent sample was taken from the chlorine contact tank adjacent the overflow weir prior to discharge to the outfall. Approximate 1.1 liter samples were taken every 10 minutes using an Eagle signal timer assembly and a submersible pump.

The composite sample aliquots were collected in 45 gallon polyethylene barrels. The 24 hour composite sampling program commenced at 0900 hr October 4 and ended at 0900 hr October 8, 1977.

The raw sewage and dechlorinated effluent grab samples were taken from the same locations as the composites. The grab samples were collected every 2 hours on October 5, 1976 from 0800 to 2000 hr.

Sample point locations are illustrated in Figure 1

2.2 Analyses

Table 4 lists the analytical parameters for the 24 hour composite sampling program. Table 5 lists the analytical parameters for the grab sampling program.

The contents of each composite sample barrel were well mixed prior to sample division. The samples for chemical analysis including metals were divided into sample bottles and preserved as outlined in the Environment Canada Pollution Sampling Handbook. Samples for bioassay analysis were placed in four-5 gallon plastic jerry cans. All samples were delivered within 2 hours to the Environment Canada laboratory facilities. Sample analysis for all parameters except metals and PCB's commenced within 3 hours of completion of each sampling day. Grab samples collected on October 5 were separated into the proper container, preserved as required and stored at 4°C before being delivered on October 6 at 1000 hour with the 24 hour composite samples.

2.2.1 Chemical Analyses. The chemical parameters including metals as listed in Tables 4 and 5 were analyzed as described in the Environment Canada Pacific Region Laboratory Manual.

2.2.2 Polychlorinated Biphenyls Analysis (PCB). Samples for PCB were collected in one gallon amber glass bottles containing 50 ml hexane as a preservative. Basically the analysis involves acetone: hexane extraction, filtration, purification and electron capture GLC analysis. The detection limit for a one gallon sample is approximately 0.005 ppb.

TABLE 4 ANALYTICAL PARAMETERS - 24 HOUR COMPOSITE SAMPLING PROGRAM

Parameter	Abbreviation	Units
Total Phosphate	TPO_4	mg/l P
Ammonia	NH_3	mg/l N
Nitrate	NO_3	mg/l N
Nitrite	NO_2	mg/l N
Total Alkalinity	-	mg/l $CaCO_3$
Chemical Oxygen Demand	COD	mg/l
Total Organic Carbon	TOC	mg/l C
pH	-	0-14 pH units
Non Filterable Residue	NFR	mg/l
Anionic Surfactants	-	mg/l LAS
Total Residue	TR	mg/l
Cyanide	CN	mg/l
Phenol	-	mg/l
Oil & Grease	-	mg/l
Polychlorinated Biphenyls	PCB	ppb
Bioassay	LC_{50}	%
Metals		
Total Mercury	Hg	µg/l
Copper, Total & Dissolved	Cu	mg/l
Iron, Total & Dissolved	Fe	mg/l
Nickel, Total & Dissolved	Ni	mg/l
Lead, Total & Dissolved	Pb	mg/l
Zinc, Total & Dissolved	Zn	mg/l
Aluminum, Total & Dissolved	Al	mg/l
Cadmium, Total & Dissolved	Cd	mg/l
Manganese, Total & Dissolved	Mn	mg/l
Chromium, Total & Dissolved	Cr	mg/l

TABLE 5 ANALYTICAL PARAMETERS - GRAB SAMPLING PROGRAM

Parameter	Abbreviation	Units
Total Phosphate	TPO_4	mg/l P
Ammonia	NH_3	mg/l N
Nitrate	NO_3	mg/l N
Nitrite	NO_2	mg/l N
Non Filterable Residue	NFR	mg/l
Chemical Oxygen Demand	COD	mg/l
Anionic Surfactants	-	mg/l LAS
Total Residue	TR	mg/l
Total Organic Carbon	TOC	mg/l C
Cyanide	CN	mg/l
Phenol	-	mg/l
Metals		
Copper, Total & Dissolved	Cu	mg/l
Iron, Total & Dissolved	Fe	mg/l
Nickel, Total & Dissolved	Ni	mg/l
Lead, Total & Dissolved	Pb	mg/l
Zinc, Total & Dissolved	Zn	mg/l
Aluminum, Total & Dissolved	Al	mg/l
Cadmium, Total & Dissolved	Cd	mg/l
Manganese, Total & Dissolved	Mn	mg/l
Chromium, Total & Dissolved	Cr	mg/l

2.2.3 Bioassay Determination (96 hour LC_{50}). The static fish bioassay test gives an approximate numerical value to the biological toxicity of wastewater. It is defined as the concentration of a measureable lethal agent (in this case wastewater) required to kill the 50th percentile in a group of test organisms over a period of 96 hours.

The static bioassay test consists of a series of 30 liter glass vessels containing different sample dilutions with 6-9 Rainbow Trout (Salmo gairdneri) per test vessel. The test vessels were placed in a controlled environment room with the temperature maintained at 14.5 $\pm$ 1.0°C and a photo period limited to 16 hours per 24 hours. The bioassay test procedures calls for samples with pH values below 6.0 or above 8.0 to be neutralized to a pH of 7; however pH adjustment was not required for any of the samples collected. All samples were aerated prior to the test and continuously, for the 96 hour period. Pre-test aeration times are listed with the test results in Table 6. The fish loading density in each vessel was 0.15 g/l. The percent mortality and percent dilution were plotted on semi-log paper to establish an LC_{50} value.

2.3 Chlorine Residual Monitoring.

The chlorine residual monitoring program consisted of grab sampling the chlorinated effluent (Sample point No. 3) every hour for 24 hours from 0900 hr October 6 to 0900 hr October 7 and determining the total residual chlorine concentration (TRC).

In addition to the monitoring program, a test was conducted to determine the effect of time on the persistence of a measurable chlorine residual. This test consisted of holding a five gallon sample of chlorinated effluent, taken from the head of the contact tank, and periodically determining the TRC of a sample aliquot.

The persistence test was conducted in an attempt to relate chlorine residual with the results of the chlorinated effluent bioassay tests.

The determination of TRC was done using a Wallace & Tiernan Amperometric Titrator series A-790013. The fundamental procedure used is a Back Titration method involving the neutralization of an oxidizing agent (free iodine) with a reducing agent (phenylarsine oxide solution) of known strength, in the presence of potassium iodide.

Total residual chlorine as determined by the amperometric Back Titration method determines the concentration of compounds in the wastewater containing active chlorine which consist of monochloramines, dichloramines and hypochlorous acid.

3 RESULTS

3.1 Bioassay Results

The static fish bioassay results obtained from the 24 hour composite samples are outlined in Table 6. The results are expressed as both a 96 hour LC_{50} as defined earlier and a toxicity concentration Tc. The toxicity concentration, Tc, expressed in toxic units, TU, can be derived as follows:

$$Tc = \frac{100\%}{96 \text{ hr } LC_{50}(\%)}$$

A Tc value can also be calculated when considering wastewater that produces less than 50 percent mortality at the 100% concentration. The actual Tc value in this case is determined by plotting the percent mortality of test fish versus the Tc values for the various test dilutions.

The average Tc values listed in Table 6 represent the average of the Tc values obtained with each bioassay determination and not the Tc which could be calculated using the average LC_{50} value. This unfortunately causes some discrepancy when comparing average LC_{50} and Tc results, which is the case with the dechlorinated effluent sample.

3.2 Chemical Analyses Non Metals - Results

The chemical analysis non-metal results obtained from the 24 hour composite samples are listed in Appendix I. A comparison of these results and the treatment level involved with each sample is illustrated in Figures 2a and 2b. The values plotted in this comparison represent the mean value from the 4-24 hour composite samples. The chemical analysis non-metal results obtained from the

TABLE 6 ANNACIS ISLAND STP COMPOSITE BIOASSAY RESULTS

Sample Point	Parameter	Units	*Oct. 5	Oct. 6	Oct. 7	Oct. 8	Average
Raw Sewage	Pre-test aeration	hr	18	19	18	23	
	LC_{50}	%	56	52	78	61	61.8
	Tc	Tu	1.79	1.92	1.28	1.64	1.66
Primary Effluent	Pre-test aeration	hr	18	19	18	23	
	LC_{50}	%	60	45.5	59.5	75	60.0
	Tc	Tu	1.67	2.20	1.68	1.33	1.72
Chlorinated Effluent	Pre-test aeration	hr	18	19	18	23	
	LC_{50}	%	43	58	53	37	47.8
	Tc	Tu	2.33	1.72	1.89	2.70	2.16
Dechlorinated Effluent	Pre-test aeration	hr	18	19	18	23	
	LC_{50}	%	26	51	75	78	57.5
	Tc	Tu	3.85	1.96	1.33	1.28	2.11

*Results obtained on October 5, 1976 were deemed unreliable due to control mortalities.

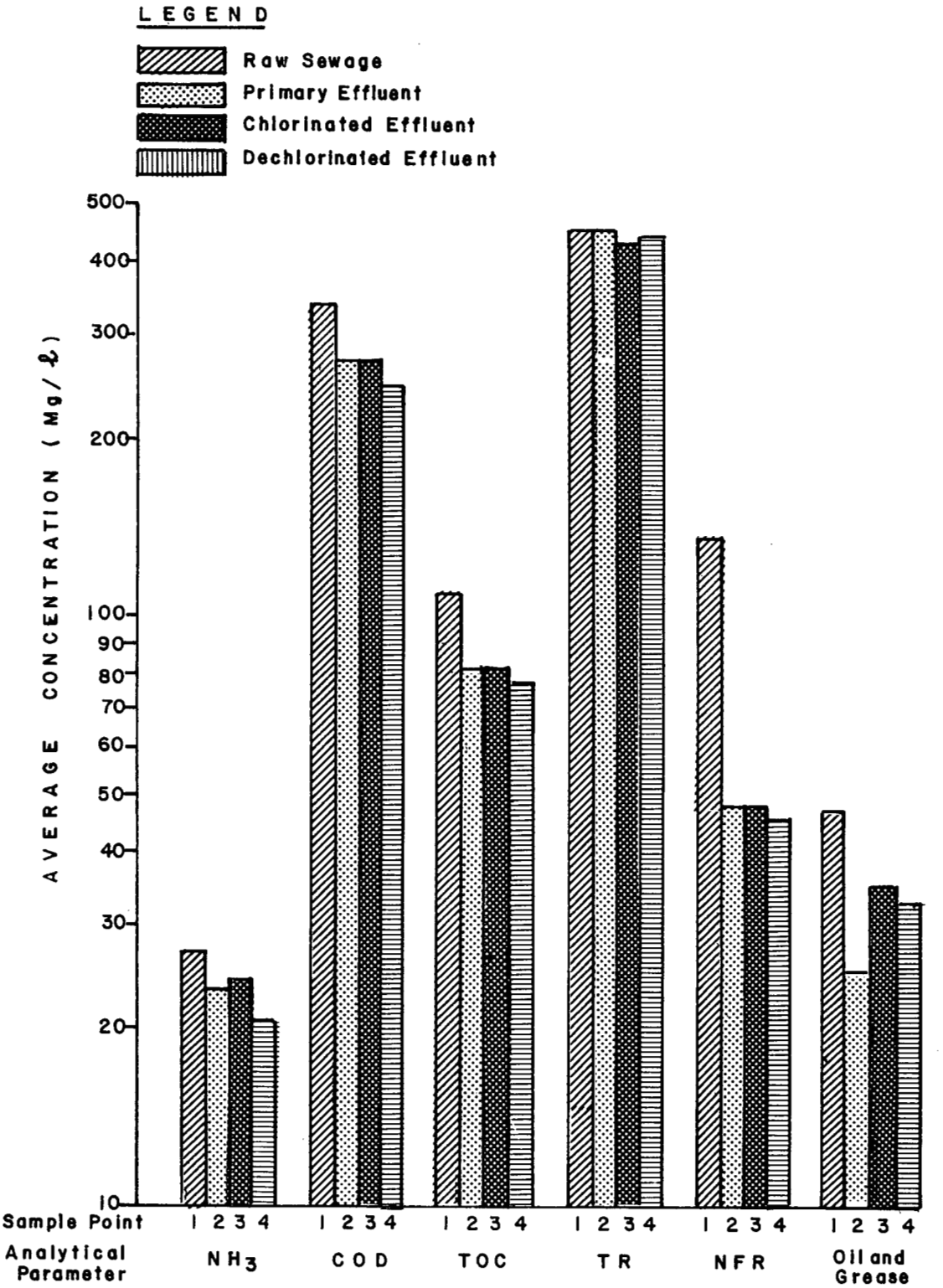

FIGURE 2a COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL

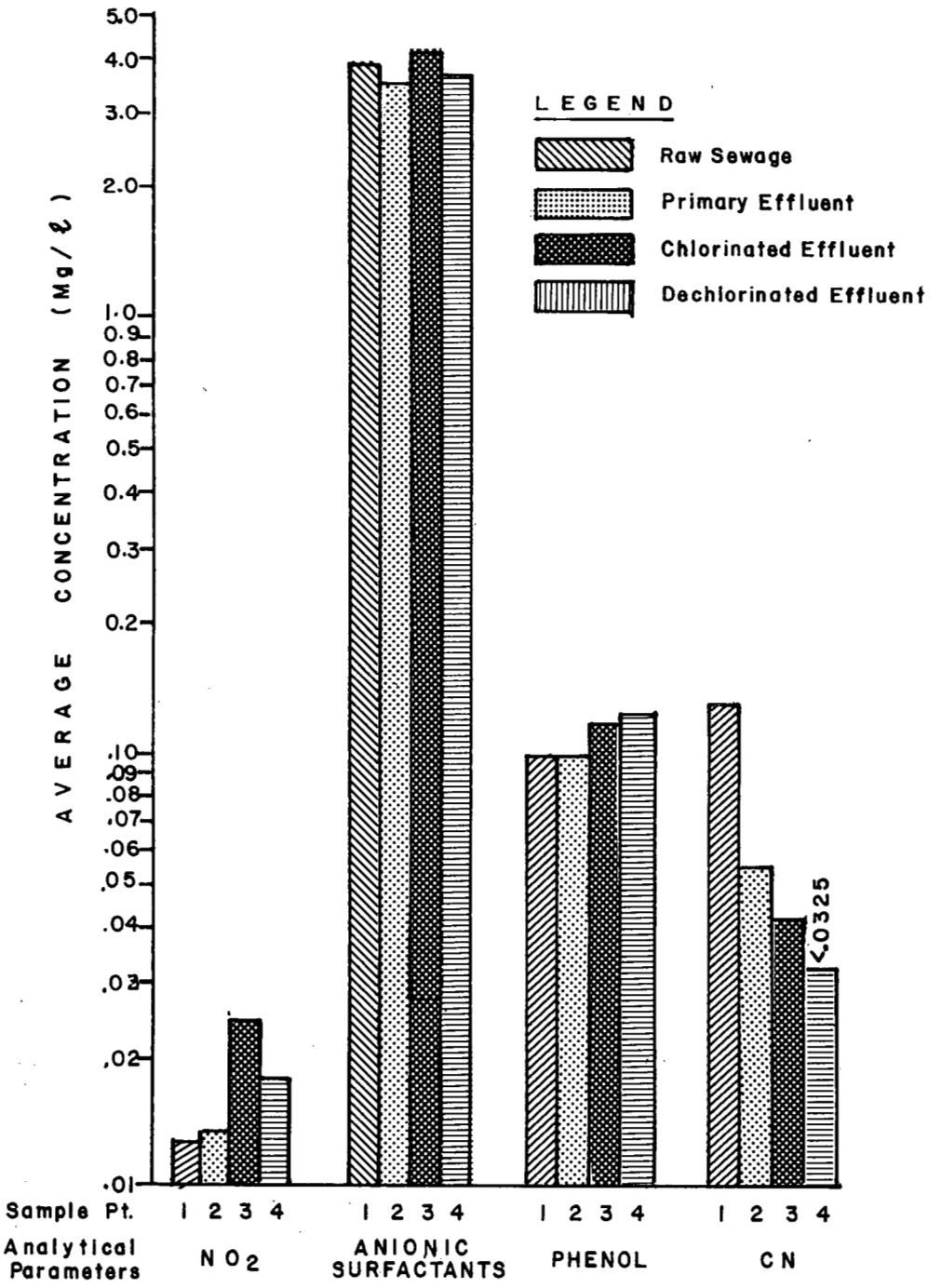

FIGURE 2b COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL

grab sampling program are outlined in Appendix II.

3.3 Chemical Analyses Metals - Results

The results of the metal analyses including total and dissolved for the 24 hour composite sampling program are presented in Appendix I. The same results for the grab sampling program are given in Appendix II.

3.4 Chlorine Residual Monitoring Results

The results of the 24 hr chlorine residual monitoring program are illustrated in Figure 3. The compound loop chlorine residual control system controlled the TRC level within a range of 0.8 - 1.6 and with a mean of 1.17 mg/l.

The results of the chlorine residual persistence test are illustrated in Figure 4. The sample had an initial TRC of 2.13 mg/l and reached a non detectable level 11.5 hours after collection.

3.5 Polychlorinated Biphenyls Results

The results of the PCB analysis for the 24 hour composite sampling program are listed in Appendix I. All levels encountered are significantly low. The treatment plant was responsible for a 42% reduction in PCB levels from influent to effluent.

3.6 Daily Flowrates, Chlorine Dosages, Sulfur Dioxide Dosages and Precipitation

Daily flowrates, chlorine dosages and sulfur dioxide dosages for a one year period from November 1, 1975 to October 31, 1976 have been plotted in Appendix III. Chlorine addition was carried out from April 28, 1976 to October 31, 1976 and sulfur dioxide addition for

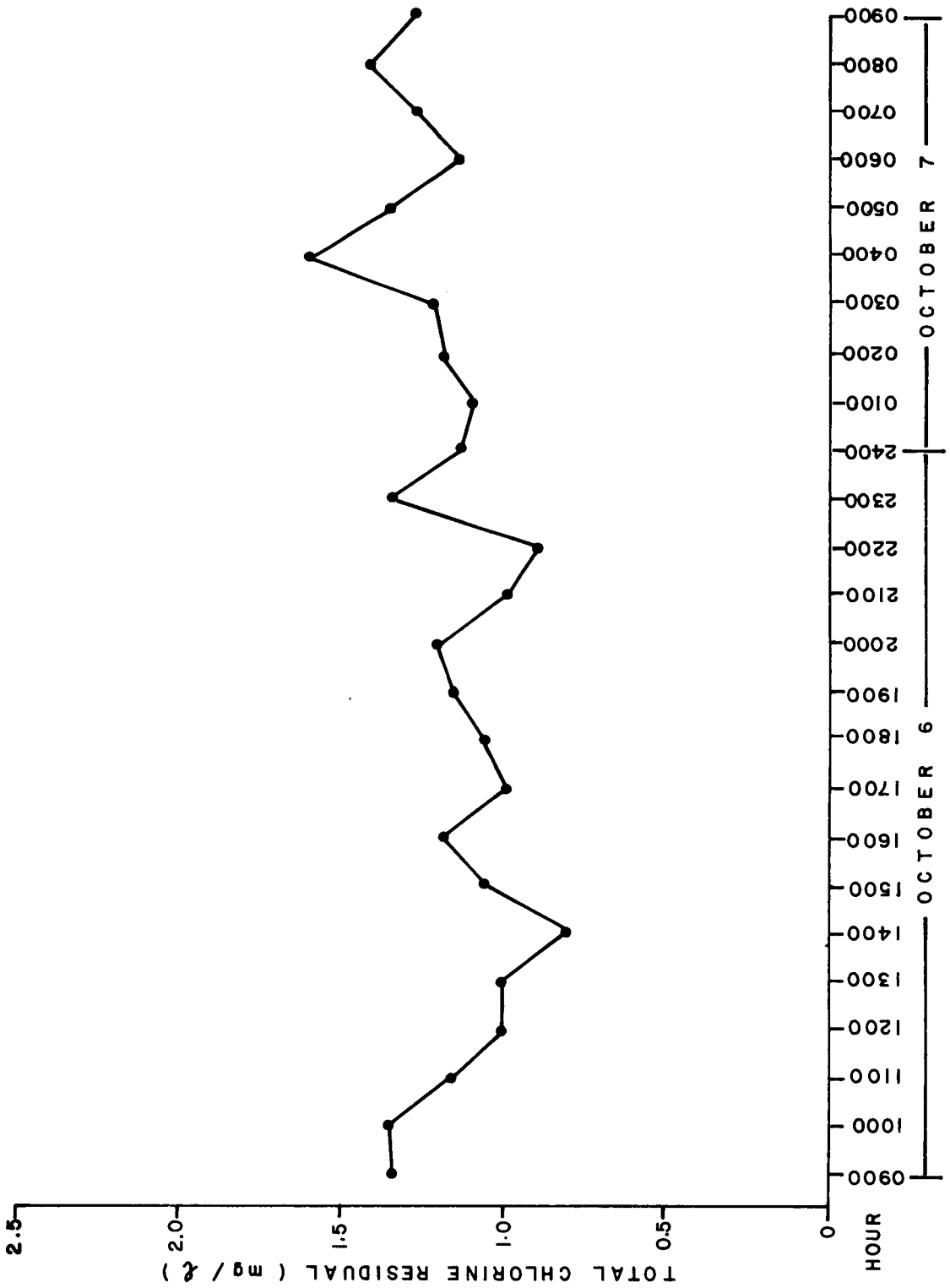

FIGURE 3 24-HOUR CHLORINE RESIDUAL MONITORING PROGRAM

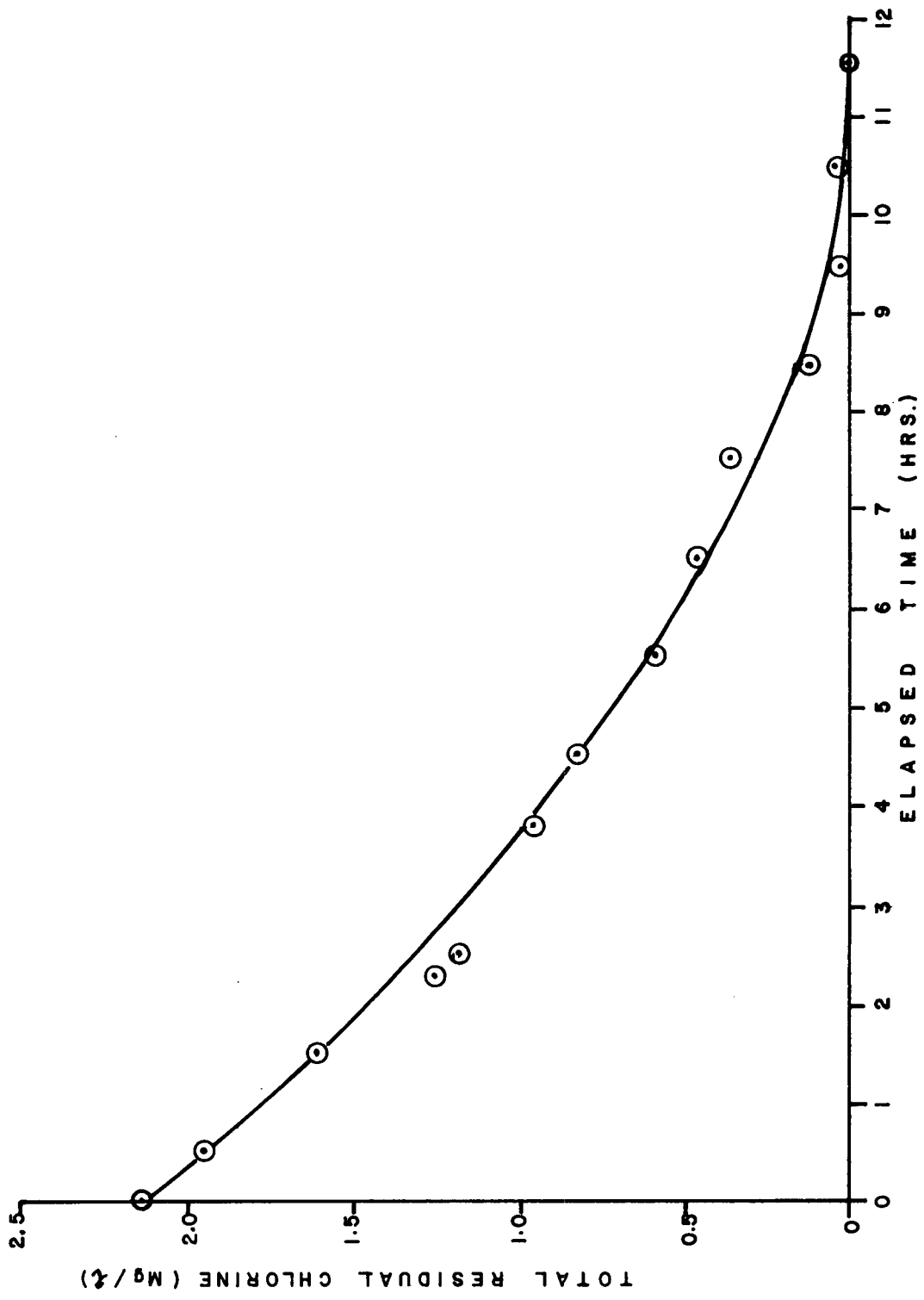

FIGURE 4 ANNACIS ISLAND STP EFFECT OF TIME ON CHLORINE RESIDUAL

effluent dechlorination commenced on July 7, 1976. Total daily precipitation data has also been included.

The plot indicates that in general the daily flow readings are influenced by precipitation. Since the sewer systems which were connected to Annacis prior to October 1976 were reportedly separate i.e. sanitary only, the increases in total daily flow which accompany periods of heavy rainfall are the result of infiltration and inflow. The major causes of infiltration are leaky manholes, faulty lateral connections and leaky pipe joints. Major sources of excessive inflow are illegal downspouts, footer drains, cross connections with storm sewers and surface runoff into inappropriately placed manholes.

Figure 5 illustrates the instantaneous flow readings taken from the flow recorder chart every two hours from 1600 hr October 4 to 0600 hr October 8. The flows reached peaks of approximately 60 CFS during the evening (1800hr - 2200 hr) while low flows of 20 - 30 CFS occured generally during the early morning (0600 hr).

3.7 Metal Analyses Summary

In addition to the metal analyses conducted during the survey on the composite samples, metal determinations were also conducted on primary digester sludge. Municipal water supply metal analyses data was provided by the Greater Vancouver Water District. A summary of the metal analyses is presented in Table 7. The results indicate a significant metal concentration increase in the raw sewage samples compared to the municipal water supply, a slight decrease in metal content of the effluent following primary treatment and a subsequent accumulation of metal in the digester sludge.

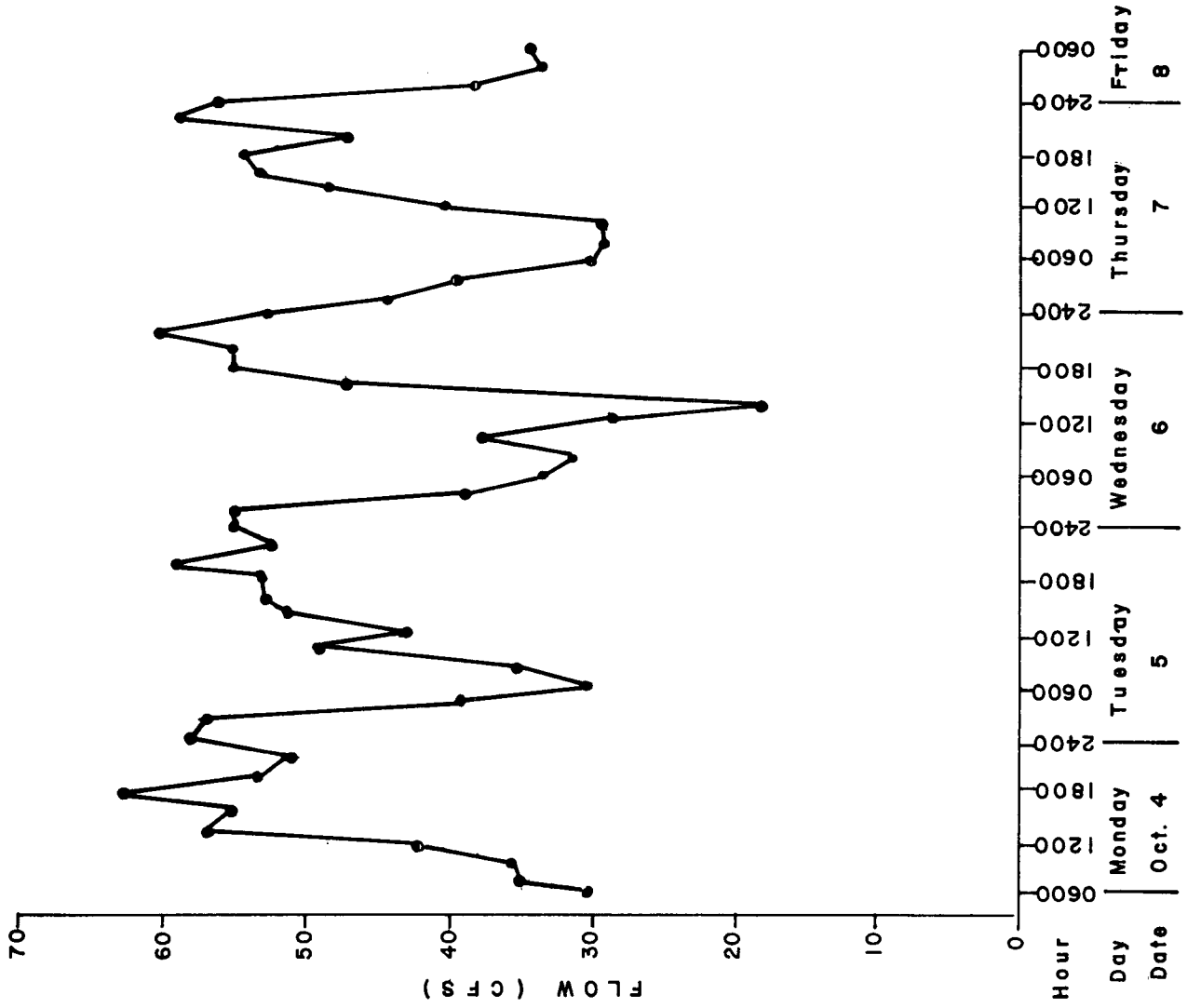

FIGURE 5 ANNACIS ISLAND STP FLOWRATES - October 4-8, 1976

TABLE 7 METAL ANALYSES SUMMARY

Metal (Total)	Influent* mg/l	Effluent* mg/l	Digester Sludge mg/l	Municipal** Water Supply mg/l
Cu	0.23	0.19	35	< 0.01
Fe	1.7	1.5	400	0.16
Ni	< 0.0055	< 0.05	-	< 0.005
Pb	< 0.023	< 0.02	11	< 0.005
Zn	0.28	0.20	35	< 0.005
Al	0.60	0.43	370	-
Cd	< 0.01	< 0.01	0.3	< 0.001
Mn	0.12	0.10	7.2	0.005
Cr	0.05	0.04	7.4	< 0.005
Hg***	< 0.35	< 0.205	73.2	< 0.5

* Average of four - 24 hr composite samples

** Results from Greater Vancouver Water District
Represents average of Capilano, Seymour and Coquitlam systems

*** Units µg/l

4 DISCUSSION

4.1 Bioassay Evaluation

Municipal wastewaters in general contain a wide variety of chemical constituents readily known to be toxic to fish. The most common constituents exerting toxicity include ammonia, cyanide, sulfides, chlorine and chloramine, phenols, surfactants and several heavy metals which include copper, zinc, chromium and nickel. Other factors such as temperature, pH, hardness, alkalinity and dissolved oxygen tend to modify the toxicity produced by various chemical constituents. However as outlined earlier the bioassay test conditions are controlled so that pH, temperature and dissolved oxygen do not themselves effect toxicity. The chemical analyses results for the individual composite samples were examined with reference to the literature to determine those factors responsible for toxicity. Following is a discussion of those factors deemed responsible for the bioassay results encountered in the survey.

4.1.1 Ammonia Toxicity. The common sources of ammonia in wastewater are:

(1) urine, which contains urea (H_2NCOH_2N) which in turn readily hydrolyzes to ammonia;
(2) organic matter containing protein and amino acids which decomposes under bacterial action yielding ammonia;
(3) chemical plants and cleaning establishments which release ammonia to the sewer system, and;
(4) household cleaning agents.

The toxicity of ammonia and ammonium salts to fish is directly related to the amount of un-ionized ammonia in solution. Ammonia establishes a pH dependent equilbrium in solution as follows:

$$NH_3 + nH_2O \rightleftharpoons NH_3 \cdot nH_2O \rightleftharpoons NH_4^+ + OH^- + (n-1)H_2O$$

Emmerson, et al (2) have outlined a set of equilibrium calculations for determining the un-ionized ammonia in solution under varying conditions of pH and temperature. The un-ionized ammonia concentrations for the 24 hour composite samples have been calculated according to this set of equations and are reported in Table 8. In addition, this table lists the bioassay results and the major toxic constituents involved for each composite sample.

Mayo et al (3) state that 0.006 mg/l N un-ionized ammonia may be considered to be the desirable upper level for extended fish exposure. A level of 0.025 mg/l un-ionized ammonia has been stated as the maximum that fish can tolerate (4). Lloyd and Orr (5) reported that 0.44 mg/l un-ionized ammonia caused 100% mortality in Salmo gairdneri in 96 hours.

The un-ionized ammonia levels reported in Table 8 fall within the 0.025-0.44 mg/l range and therefore would be expected to contribute significantly to wastewater toxicity. However, as pointed out by Esvelt, Kaufman & Selleck (6) it should be noted that factors in addition to un-ionized ammonia may be associated with the toxicity of ammonia. A full discussion of these factors is beyond the scope of this report.

4.1.2 Surfactant Toxicity. Detergents are a common component of sewage and industrial effluents, derived in largest amounts from household cleaning agents. Surfactants can be divided as being either anionic, cationic or non-ionic. In current detergent formulas, the primary toxic active agent is LAS (linear alkylate sulfonates) an anionic surfactant. The surfactant analysis conducted during this survey was carried out specifically for LAS.

The toxicity of LAS tends to increase in hard water, and increase as the carbon chain length increases (6).

TABLE 8 COMPARISON OF ANALYTICAL AND BIOASSAY RESULTS

Sample Points	Date	LC_{50}	Tc	NH_3	Un-ionized* NH_3	pH	Anionic Surfactants	Control Mortalities
	October	%	TU	mg/l N	mg/l N		mg/l LAS	%
Raw Sewage	5	56	1.79	40	0.17	7.2	4.5	20
	6	52	1.92	27	0.023	6.5	4.6	0
	7	78	1.28	21	0.046	6.9	4.6	0
	8	61	1.64	20.5	0.077	7.1	4.5	0
Primary Effluent	5	60	1.67	24	0.066	7.0	3.7	20
	6	45.5	2.20	28	0.048	6.8	2.7	0
	7	59.5	1.68	21	0.036	6.8	3.9	0
	8	75	1.33	20.5	0.056	7.0	3.4	0
Chlorinated Effluent	5	43	2.33	25	0.054	6.9	3.7	20
	6	58	1.72	28	0.069	6.9	2.8	0
	7	53	1.89	22	0.036	6.8	3.8	0
	8	37	2.70	21.5	0.059	7.0	3.5	0
Dechlorinated Effluent	5	26	3.85	21	0.046	6.9	3.7	20
	6	51	1.96	21	0.036	6.8	4.0	0
	7	75	1.33	20	0.034	6.8	4.2	0
	8	78	1.28	20	0.043	6.9	3.5	0

*According to Emmerson et al (2)

Thatcher and Santner (8) found 96 hr LC_{50} values for LAS of 3.3-6.4 mg/l for five species of fish. Dolan and Hendricks determined an LC_{50} of 5.9 mg/l LAS for bluegill sunfish (9). The anionic surfactant concentrations for the raw sewage samples as outlined in Table 8 would be expected to contribute to wastewater toxicity.

4.1.3 Chlorine Toxicity. The toxicity of chlorine and other chlorinated compounds such as chloramines and chlorinated hydrocarbons has been throughly documented in the literature. Martens and Servizi (10) observed that the toxicity of primary treated sewage to sockeye salmon was increased several fold whenever chlorine residuals were detected in the effluent. In field studies, residual chlorine levels above 0.02 mg/l were found likely to be toxic to rainbow trout and sockeye salmon using in-stream bioassay techniques (10).

The toxicity of chlorinated wastewater does not depend directly on the amount of chlorine added but on the concentration of residual chlorine remaining (11). Residual chlorine is commonly understood to mean the total concentration of compounds containing active chlorine which remain after free chlorine addition. These compounds consist of monochloramines, dichloramines and hypochlorous acid. In addition chlorine may combine with a variety of compounds in wastewater including cyanide, phenols and alkyl sulfonate, which are not detectable by the amperometric technique.

Residual chlorine is known to decrease with time owing to reaction with substances in sewage. Marten and Servizi (10) reported in a test of chlorinated primary sewage that the residual chlorine decreased significantly from 2.6 mg/l during the first 10 hr but assumed a virtually constant value of 0.2 mg/l which persisted beyond 50 hr. A similar test was conducted during this survey; the results, plotted in Figure 4, indicate that a measurable chlorine residual persisted for 11.5 hr. Since as reported in Table 6 all bioassay samples were aerated from 18- 23 hr prior to the time bioassay determinations commenced, it could be assumed that TRC would be non-

detectable in the bioassay test vessels even at the 100% concentration. The bioassay results indicate that there is an increase in toxicity associated with chlorination (Tc increase from 1.72 to 2.16 TU) which can not be attributed to a measureable chlorine residual.

4.2 Bioassay Summary

As mentioned previously the bioassay results and the major toxic constituents involved for each composite sample are listed in Table 8. Also included in this table is the percent mortalities of the test fish in the control sample associated with each set of bioassay samples. Attention is drawn to the 20% control mortality which occurred with the first set of samples. Therefore the results obtained on October 5 are questionable, and the average LC_{50} and Tc values stated in Table 8 are somewhat distorted. It is recognized that the bioassay results obtained during the survey are not definitive, due to the short survey period and the number of samples involved. Reference is made to the study carried out by the International Pacific Salmon Fisheries Commission titled, Acute Toxicity of Sewage at Annacis Island, which involved sampling over a much longer period of time. This report has not yet been published.

A comparison of the toxicity concentration, Tc of the 24 hour composite samples obtained from the four treatment plant locations is illustrated in Figure 6.

The raw sewage exhibited a mean 96 hr LC_{50} of 61.8% (Tc = 1.66). The un-ionized ammonia level (0.08 mg/l N) and the anionic surfactant concentration (4.55 mg/l LAS) would be expected to exert a toxic effect.

The primary effluent exhibited a mean 96 hr LC_{50} of 60.0% (Tc = 1.72), indicating virtually no change in toxicity due to primary treatment.

The chlorinated effluent exhibited a mean 96 hr LC_{50} of 47.8% (Tc = 2.16), a 30% increase based on the raw sewage samples. Since there is only a slight reduction in the un-ionized ammonia and surfactant concentrations (0.05 mg/l N, 3.45 mg/l LAS) after primary treatment; chlorination could be assumed responsible for the increase in toxicity. However the precise compounds responsible for chlorine

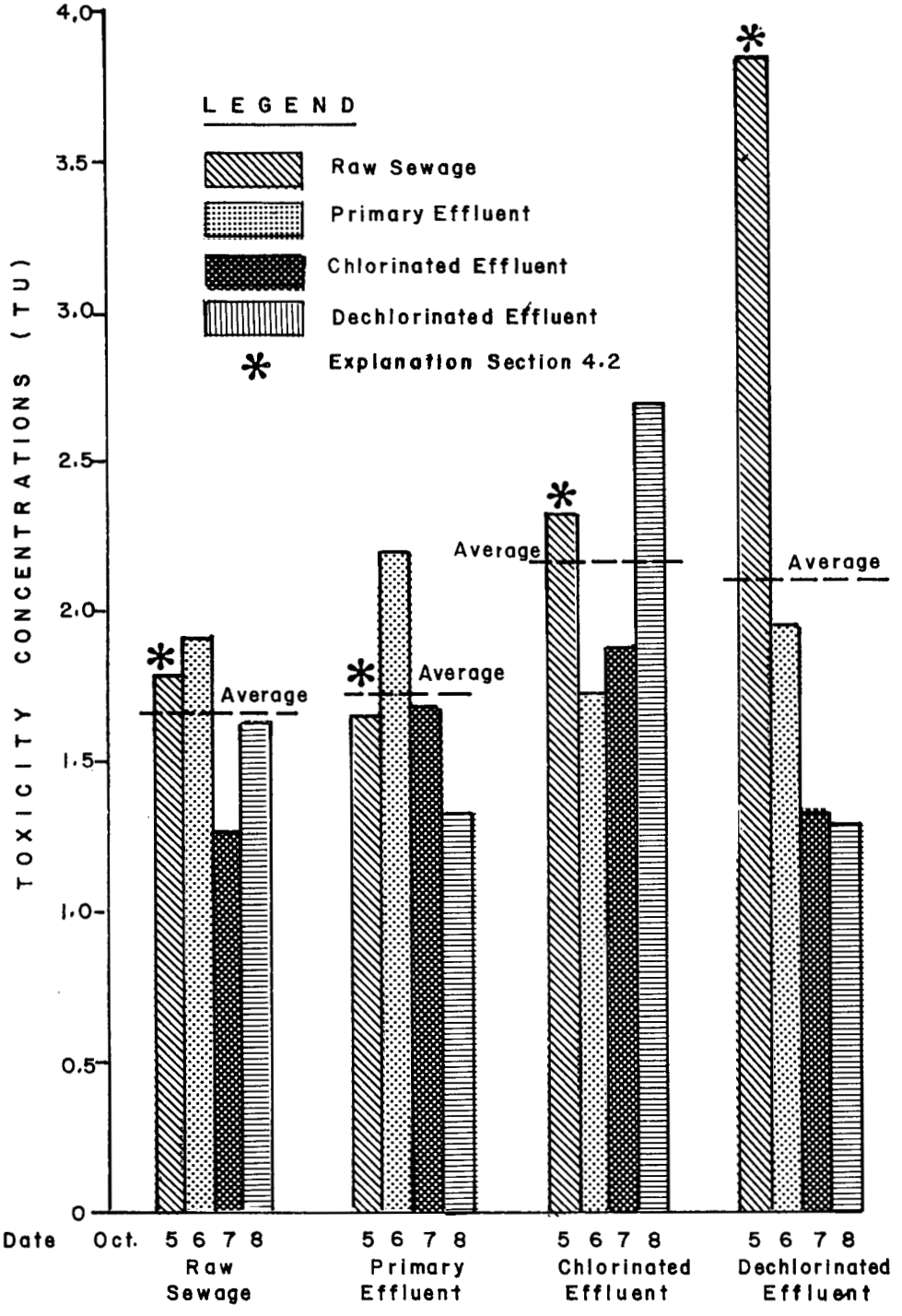

FIGURE 6 ANNACIS ISLAND STP BIOASSAY RESULTS, TOXICITY CONCENTRATIONS - October 5-8, 1976

induced toxicity have not been determined and a full discussion of the factors involved is beyond the scope of this report. In addition as pointed out in Section 4.1.3 in this case, chlorine induced toxicity is not necessarily related to a measureable residual.

The dechlorinated effluent exhibited a mean 96 hr LC_{50} of 57.5% (Tc = 2.11) indicating that dechlorination resulted in a slight decrease in toxicity, by comparison to the chlorinated effluent sample The un-ionized ammonia (0.04 mg/l N) and surfactant concentrations (3.85 mg/l LAS) could be expected to exert a toxic effect. However it should be pointed out that since both these parameters are at relatively low levels, parameters other than those investigated during the composite sampling program may be responsible for wastewater toxicity.

If the results obtained on the first day of sampling are ignored due to the mortalities in the control bioassay, the results in general remain unchanged except for the dechlorinated effluent mean Tc which drops to 1.52. This would tend to indicate that dechlorination using SO_2 is effective in eliminating chlorine induced toxicity.

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APPENDICES

APPENDIX I

ANNACIS ISLAND STP
COMPOSITE SAMPLE ANALYTICAL RESULTS

a. NON METALS

b. METALS

Appendix I Annacis Island STP Composite Sample Analytical Results
a. Non Metals

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3
Dechlorinated Effluent	4

Analytical Parameter	Sampling Point	Date Oct. 5	Oct. 6	Oct. 7	Oct. 8
TPO_4 mg/l P	1	6.4	12	6.0	6.4
	2	6.3	10	5.6	5.7
	3	7.4	11	6.0	6.2
	4	6.8	11	5.3	5.7
NH_3-N mg/l N	1	40	27	21	20.5
	2	24	28	21	20.5
	3	25	28	22	21.5
	4	21	21	20	20
NO_3-N mg/l N	1	<0.01	<0.01	<0.01	<0.01
	2	<0.01	<0.01	<0.01	<0.01
	3	0.058	<0.01	<0.01	<0.01
	4	<0.01	<0.01	<0.01	<0.01
NO_2-N mg/l N	1	0.01	0.015	0.012	0.015
	2	0.011	0.013	0.014	0.016
	3	0.022	0.027	0.025	0.025
	4	0.015	0.023	0.018	0.017
Alkalinity mg/l $CaCO_3$	1	150	89	120	116
	2	120	110	110	116
	3	105	97	91	85
	4	100	67	94	89
pH	1	7.2	6.5	6.9	7.1
	2	7.0	6.8	6.8	7.0
	3	6.9	6.9	6.8	7.0
	4	6.9	6.8	6.8	6.9
NFR mg/l	1	107	150	120	160
	2	48	54	49	39
	3	50	48	49	44
	4	43	45	47	47

Appendix I Annacis Island STP Composite Sample Analytical Results
a. Non Metals (cont'd)

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3
Dechlorinated Effluent	4

Analytical Parameter	Sampling Point	Date Oct. 5	Oct. 6	Oct. 7	Oct. 8
COD mg/l	1	330	380	360	290
	2	270	250	280	290
	3	260	250	300	280
	4	250	240	290	210
Anionic Surfactant mg/l LAS	1	4.5	3.7	3.7	3.7
	2	4.6	2.7	2.8	4.0
	3	4.6	3.9	3.8	4.2
	4	4.5	3.4	3.5	3.5
TR mg/l	1	450	360	460	540
	2	520	380	440	460
	3	380	370	460	490
	4	410	410	450	470
TOC mg/l C	1	115	110	115	92
	2	98	76	85	67
	3	62	79	104	78
	4	71	65	80	90
CN mg/l	1	<0.03	0.38	0.04	0.07
	2	<0.03	0.06	0.07	0.06
	3	<0.03	0.04	0.04	0.06
	4	<0.03	<0.03	0.04	0.03
Phenol mg/l	1	0.06	0.12	0.104	0.11
	2	0.074	0.087	0.091	0.14
	3	0.075	0.15	0.134	0.11
	4	0.080	0.16	0.142	0.12
Oils & Grease mg/l	1	52	55	33	47
	2	28	24	23	-
	3	30	28	35	48
	4	34	28	30	39
PCB ppb	1	0.079	.027	.056	.072
	2	0.062	.028	.120	.052
	3	-		-	
	4	0.067	.024	.021	.023

Appendix I Annacis Island STP Composite Sample Analytical Results
b. Metals

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3
Dechlorinated Effluent	4

Analytical Parameter	Sampling Point	Date Oct. 5	Oct. 6	Oct. 7	Oct. 8
Hg Total µg/l	1	<0.20	0.52	0.25	0.44
	2	<0.20	0.21	0.25	0.25
	3	<0.20	<0.20	<0.20	<0.20
	4	<0.20	<0.20	0.21	0.21
Cu Total mg/l	1	0.23	0.24	0.22	0.23
	2	0.20	0.18	0.17	0.16
	3	0.20	0.18	0.17	0.19
	4	0.21	0.20	0.18	0.18
Cu Dissolved mg/l	1	0.05	<0.01	0.08	0.06
	2	0.03	0.02	0.07	0.05
	3	0.17	0.13	0.14	0.15
	4	0.03	0.14	0.06	0.05
Fe Total mg/l	1	1.5	1.9	1.6	1.8
	2	1.3	1.4	1.3	1.4
	3	1.4	1.4	1.4	1.4
	4	1.4	1.8	1.4	1.4
Fe Dissolved mg/l	1	0.86	0.85	0.76	0.80
	2	0.78	0.69	0.93	0.79
	3	0.72	0.60	0.60	0.64
	4	0.78	0.71	0.80	0.78
Ni Total mg/l	1	0.07	<0.05	<0.05	<0.05
	2	0.08	<0.05	<0.05	0.06
	3	<0.05	<0.05	0.07	<0.05
	4	0.05	0.07	0.08	0.07
Ni Dissolved mg/l	1	0.06	<0.05	<0.05	<0.05
	2	0.05	<0.05	<0.05	<0.05
	3	<0.05	<0.05	<0.05	<0.05
	4	<0.05	<0.05	<0.05	<0.05
Pb Total mg/l	1	0.03	<0.02	<0.02	<0.02
	2	0.02	0.02	<0.02	<0.02
	3	0.02	0.02	<0.02	<0.02
	4	0.02	0.02	<0.02	<0.02
Pb Dissolved mg/l	1	0.02	<0.02	<0.02	<0.02
	2	<0.02	0.02	<0.02	<0.02
	3	0.03	<0.02	<0.02	<0.02
	4	0.02	0.02	<0.02	<0.02

Appendix I Annacis Island STP Composite Sample Analytical Results
b. Metals (cont'd)

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3
Dechlorinated Effluent	4

Analytical Parameter	Sampling Point	Date			
		Oct. 5	Oct. 6	Oct. 7	Oct. 8
Zn Total mg/l	1	0.41	0.26	0.19	0.24
	2	0.15	0.19	0.18	0.17
	3	0.17	0.21	0.26	0.17
	4	0.18	0.21	0.19	0.22
Zn Dissolved mg/l	1	0.10	0.11	0.06	0.10
	2	0.08	0.12	0.09	0.10
	3	0.12	0.16	0.16	0.15
	4	0.12	0.16	0.16	0.15
Al Total mg/l	1	0.7	0.6	0.5	0.6
	2	0.4	0.4	0.3	0.3
	3	0.4	0.5	0.5	0.4
	4	0.3	0.5	0.5	0.4
Al Dissolved mg/l	1	<0.3	<0.3	<0.3	<0.3
	2	<0.3	<0.3	<0.3	<0.3
	3	<0.3	<0.3	<0.3	<0.3
	4	<0.3	<0.3	<0.3	<0.3
Cd Total mg/l	1	<0.01	<0.01	<0.01	<0.01
	2	<0.01	<0.01	<0.01	<0.01
	3	<0.01	<0.01	<0.01	<0.01
	4	<0.01	<0.01	<0.01	<0.01
Cd Dissolved mg/l	1	<0.01	<0.01	<0.01	<0.01
	2	<0.01	<0.01	<0.01	<0.01
	3	<0.01	<0.01	<0.01	<0.01
	4	<0.01	<0.01	<0.01	<0.01
Mn Total mg/l	1	0.11	0.11	0.12	0.12
	2	0.10	0.09	0.10	0.11
	3	0.09	0.10	0.10	0.10
	4	0.10	0.10	0.11	0.11
Mn Dissolved mg/l	1	0.09	0.09	0.09	0.08
	2	0.08	0.09	0.10	0.09
	3	0.07	0.08	0.09	0.09
	4	0.07	0.09	0.08	0.09
Cr Total mg/l	1	0.05	0.05	0.05	0.05
	2	0.03	0.05	0.05	0.05
	3	0.03	0.04	0.04	0.04
	4	0.03	0.05	0.04	0.05
Cr Dissolved mg/l	1	0.03	0.03	0.02	0.02
	2	<0.02	0.03	0.03	0.02
	3	0.03	0.03	0.02	0.03
	4	0.03	0.03	0.03	0.03

APPENDIX II

ANNACIS ISLAND STP
GRAB SAMPLE ANALYTICAL RESULTS

a. NON METALS

b. METALS

Appendix II Annacis Island STP Grab Sample
Analytical Results - October 5, 1976
a. Non Metals

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Dechlorinated Effluent	4

Analytical Parameters	Point	Time						
		0800	1000	1200	1400	1600	1800	200
TPO_4	1	7.6	8.1	9.1	8.7	13.0	22.0	10.0
mg/l P	2	7.8	8.8	12.0	9.2	7.9	9.0	12.0
	4	8.3	9.3	11.0	9.1	7.8	10.0	9.4
NH_3-N	1	22	23	24	27	27	27	27
mg/l N	2	22	19	21	22	26	26	30
	4	21	19	19	23	27	28	30
NO_3-N	1	<.01	<.01	<.01	<.01	<.01	<.01	<.01
mg/l N	2	<.01	<.01	.065	<.01	.10	<.01	<.01
	4	<.01	<.01	.077	<.01	<.01	.07	.45
NO_2-N	1	.006	.009	.010	.013	.013	.037	.015
mg/l N	2	.019	.016	.075	.021	.019	.019	.025
	4	.016	.015	.083	.021	.016	.021	.021
NFR	1	79	100	160	120	130	480	150
mg/l	2	43	35	42	38	43	45	55
	4	39	35	35	37	39	51	51
COD	1	310	640	320	330	350	5800	440
mg/l	2	250	740	240	240	200	230	270
	4	170	720	230	210	920	230	280
Anionic	1	2.5	2.5	2.9	2.1	2.6	2.3	2.8
Surfactants	2	3.4	2.7	2.9	2.5	2.1	2.3	3.2
mg/l LAS	4	3.5	1.8	2.6	2.6	2.1	2.6	2.6
TR	1	600	560	370	450	440	1000	630
mg/l	2	420	440	440	300	370	410	500
	4	450	390	450	310	340	410	490
TOC	1	73	91	84	97	77	213	118
mg/l	2	81	78	65	64	55	69	103
	4	85	71	66	69	69	79	77
CN	1	0.05	0.09	0.04	0.05	0.03	0.05	0.08
mg/l	2	0.16	0.16	0.03	0.11	0.14	0.05	0.10
	4	<0.03	<0.03	<0.03	<0.03	0.03	0.11	0.03
Phenol	1	0.041	0.071	0.40	0.200	0.12	0.037	0.61
mg/l	2	0.052	0.075	0.64	0.780	0.11	0.13	0.16
	3	0.066	0.097	0.11	0.061	0.083	0.15	0.15

Appendix II Annacis Island STP Grab Sample
Analytical Results - October 5, 1976
b. Metals

Sampling Point	Number
Raw Sewage	1
Dechlorinated Effluent	4

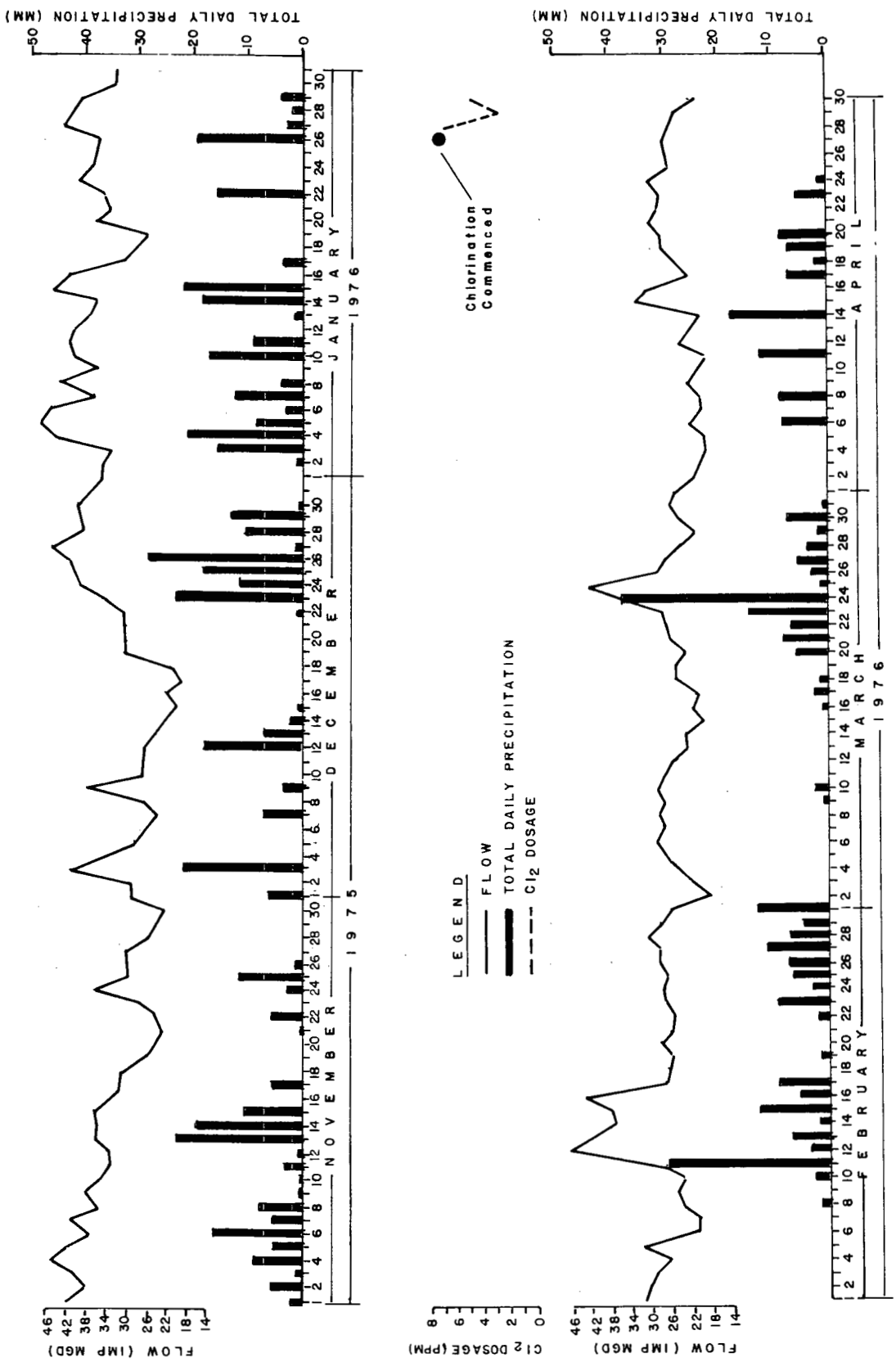
Analytical Parameters mg/l		Point	Time						
			0800	1000	1200	1400	1600	1800	2000
Cu	T*	1	0.17	0.25	0.20	0.32	0.22	0.50	0.25
		4	0.15	0.13	0.33	0.20	0.15	0.18	0.20
Cu	D**	1	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01
		4	0.12	0.10	0.26	0.16	0.11	0.13	0.13
Fe	T	1	1.6	1.9	2.3	2.6	1.9	4.3	2.0
		4	1.3	1.3	1.4	1.4	1.4	1.4	1.5
Fe	D	1	0.66	0.87	0.95	0.74	0.87	2.3	1.1
		4	0.69	0.69	0.66	0.60	0.51	0.46	0.61
Ni	T	1	0.08	0.07	<0.05	<0.05	<0.05	<0.05	<0.05
		4	0.07	<0.05	0.08	<0.05	<0.05	<0.05	<0.05
Ni	D	1	0.07	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		4	0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05
Pb	T	1	0.02	<0.02	0.04	0.23	0.39	0.63	0.03
		4	0.02	<0.02	0.021	0.29	0.16	0.42	0.04
Pb	D	1	<0.02	<0.02	0.02	<0.02	0.02	0.02	<0.02
		4	0.02	0.02	0.03	0.03	0.02	<0.02	<0.02
Zn	T	1	4.0	0.31	0.23	0.023	0.39	0.63	0.37
		4	0.57	0.12	0.30	0.29	0.16	0.42	0.38
Zn	D	1	0.10	0.10	0.07	0.09	0.08	0.19	0.11
		4	0.09	0.07	0.27	0.20	0.22	0.27	0.15
Al	T	1	0.5	0.3	0.9	1.3	0.9	1.6	0.6
		4	0.4	<0.3	<0.3	0.3	0.5	0.5	0.4
Al	D	1	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	0.3
		4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Cd	T	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cd	D	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mn	T	1	0.12	0.09	0.12	0.14	0.11	0.17	0.10
		4	0.09	0.10	0.10	0.10	0.10	0.10	0.11
Mn	D	1	0.07	0.08	0.10	0.09	0.07	0.14	0.10
		4	0.07	0.08	0.09	0.08	0.08	0.06	0.08
Cr	T	1	0.06	0.05	0.05	0.04	0.06	0.11	0.05
		4	0.03	0.03	0.05	0.05	0.03	0.06	0.07
Cr	D	1	<0.02	0.03	<0.02	0.02	0.03	0.05	0.03
		4	<0.02	<0.02	0.03	0.03	0.02	0.03	0.07

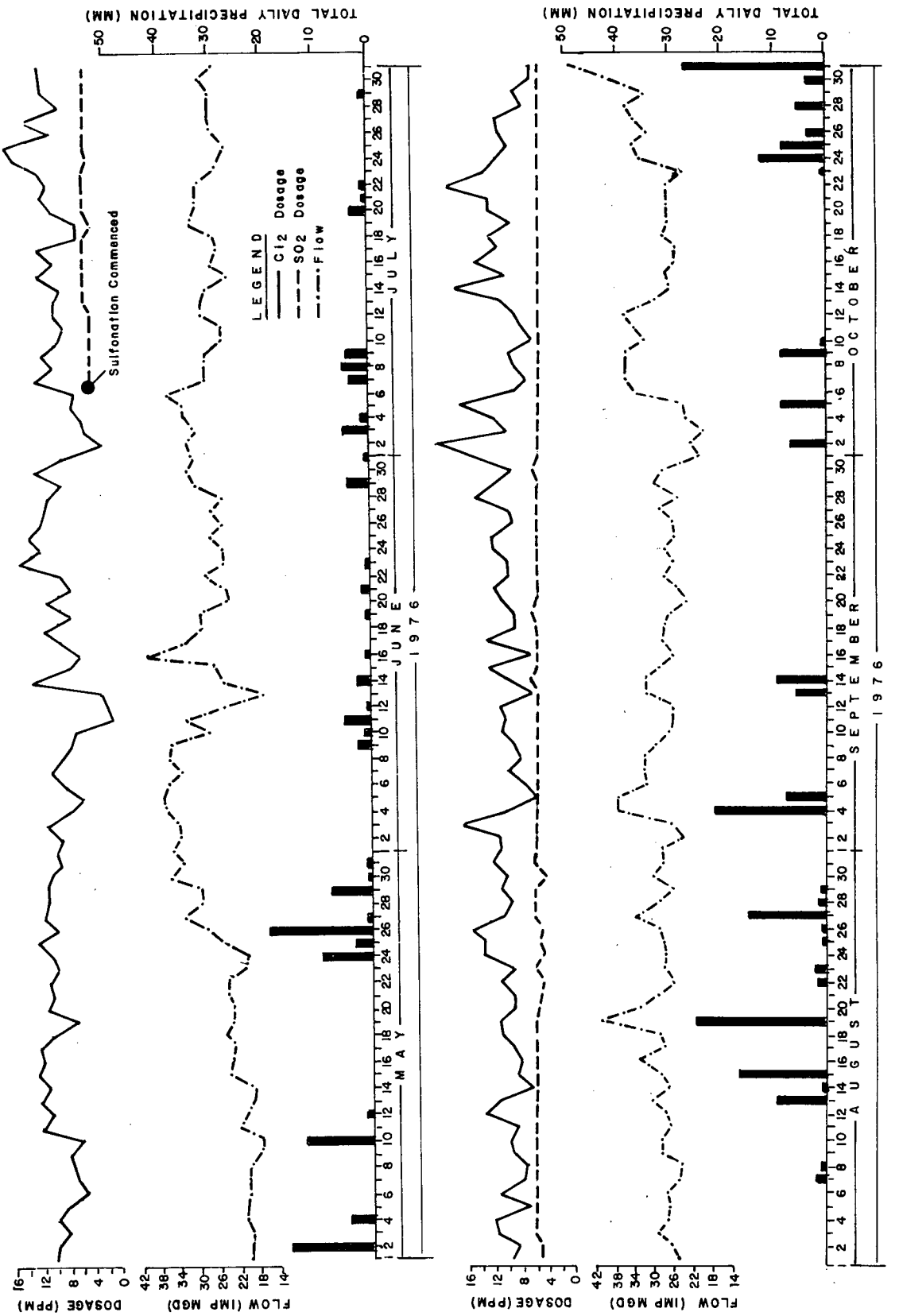
* T - Total
** D - Dissolved

APPENDIX III

ANNACIS ISLAND STP, DAILY FLOWS, CHLORINE DOSAGES, SULFUR DIOXIDE DOSAGES AND PRECIPITATION

November 1, 1975 to October 31, 1976


TOTAL DAILY PRECIPITATION (MM)
FLOW (IMP MGD)
Cl2 DOSAGE (PPM)
Chlorination Commenced
LEGEND
FLOW
TOTAL DAILY PRECIPITATION
Cl2 DOSAGE
NOVEMBER 1975
DECEMBER
JANUARY 1976
FEBRUARY
MARCH
APRIL 1976


TOTAL DAILY PRECIPITATION (MM)
Sulfonation Commenced
LEGEND
Cl2 Dosage
SO2 Dosage
Flow
DOSAGE (PPM)
FLOW (IMP MGD)
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1976